



Analysis of incomplete filling defect for injection molded thin-shell container using MOLDEX 3D simulation

Sameer Nagpure¹, Chadge RB²

1. Production Engineering, Department of Mechanical Engineering, Yeshwantrao Chavan College of Engineering, Nagpur, India, Email: sameer_nagpure@yahoo.in

2. Assistant Professor, Department of Mechanical Engineering, Yeshwantrao Chavan College of Engineering, Nagpur, India, Email: rbchadge@rediffmail.com

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General Note



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ABSTRACT

Nowadays, Plastic Injection Molding (PIM) is one of the most popular and important polymer processing operations in plastic industry. PIM gives high production rate at low cost and capability to produce intricate parts with higher precision. This research highlights the problems identified in ABC industry in Nagpur, Maharashtra. During inspection, it was found that filling of molten metal in Amul ice cream container was incomplete and unfilled sections. This incomplete filling of molten metal is known as short shot. The recent product batches faced 15% of total rejection. The Moldex3D simulation software was used with current processing parameters to analyse the defect. Analysis results show that unbalanced filling (74%) and incomplete sections occurs due to incorrect process parameters. To reduce this defect we optimize the process parameters using Moldex3D simulation. The results show that short shot defect eliminated completely.

Keywords: Plastic Injection Molding (PIM); Moldex3D; Short Shot; Melt temperature; Packing Pressure; trial and error approach.

1. INTRODUCTION

Plastic injection molding is one of the most commonly used manufacturing processes for the fabrication of plastic parts in net shape with excellent dimensional tolerance. A wide variety of products are manufactured using PIM like automobile bumpers, mobile phone housings, television cabinets, compact discs, toys and industrial. These plastic products have some advantages: lightweight, high stiffness, no post-processing operations, ease of manufacturing and high productivity. John Wesley is a pioneer scientist who invented injection molding first time by injecting celluloid into a mold which resulted in billiard balls. PIM uses plastic in the form of pellets or granules as a raw material. A plastic material is melted in the injection molding machine and then injected into the mold, where it cools and solidifies into the final part. The most commonly used thermoplastics are polystyrene, polypropylene, polyvinyl chloride, and acrylonitrile-butadiene-styrene (ABS) [1]. Plastic Injection molding process is a complex technology with possible production problems. These problems can either be caused by defects in the molds or more often by incorrect process parameters such as melt temperature, mold temperature, injection pressure, packing pressure, filling time and cooling time [2]. Many process parameters are involved and have a great influence on the quality of final products. To reduce defects effectively, two ways are considered: one is to redesign the mold if necessary, the other is to find the optimum process parameters. In general, the mold is designed at the early stage of the design process, and the change of the mold design is then costly and difficult [3]. In contrast, the process parameters can be easily optimized before process with the help of simulation software. A computer-aided engineering (CAE) simulation technique is a helpful approach. Benefits that have been identified from experienced users of analysis programmed are better part quality, reduced tooling lead times, optimum cycle times, and reduce rework and scrap materials. The injection molding CAE package includes Moldex3D, Moldflow, soft sigma, etc.

The study was carried out at ABC industry. Since Amul ice cream container is largest producing product of the industry, high process defects of this product is industry's major concern. The data collection was limited to two batch of July 2015. The combined two batch average of the short shot defects were about 60% of the total type of defects. Short shot occurs when the melt temperature is too low and insufficient filling time. The objective is to optimize process parameters related to short shot so that waste generated during setting the correct process parameter with conventional trial-and-error approach can be eliminated. Many simulation studies were performed to determined potential problems and their most economical solutions. Hyeyoung Shin and EunSoo Park [1] have analysed injection molding defects in thin shell air cleaner cover using Moldflow simulation. As revealed, inadequate mold design results to a poor plastic filling behaviour and a reduced filling rate of molten metal into the mold cavity. The design single manifold with six runners solved the short shot problem. HasanOktem et al. [4] have successfully applied Taguchi optimization technique to find the optimum levels of process parameters used in injection of thin-shell plastic components. A verification test was conducted using simulaton software to solve the problems associated with defect.

2. PRESENET THEORY AND PRACTICES

The industry employs trial and error approach to set process parameters which are not optimum. Unfortunately, adjusting the process parameters through trial and error approach is a time consuming task. In conventional method, all the process parameters which are input to the injection molding machine given in range, so the operator have to set the process parameters by taking some trials, which is not convenient. This conventional method leads to increase in cycle time, more scrap and rework, low productivity, wastage of man hours, capital, etc. Therefore to avoid such inconvenience, plastic industries widely incorporated injection molding simulation software Moldex3D. It allows the user to find out influencing parameters for a particular defect and provides a way to optimize it. To achieve good quality of products, simulation software is helpful with no scrap and rework. The most important parameter cycle time of product can be reduced to increase productivity.

3. MOLDEX3D ANALYSIS

Moldex3D helps you simulate and visualize versatile injection molding processes to validate and optimize your plastic designs, increase manufacturability, shorten time to market and maximize Return on Investment. Moldex3D CAE software provides the true 3D simulation and visualization technology you need if you are fed up with countless trial-and-errors and want to save time, energy, and money more efficiently during the mold making process.

3.1. Part under study

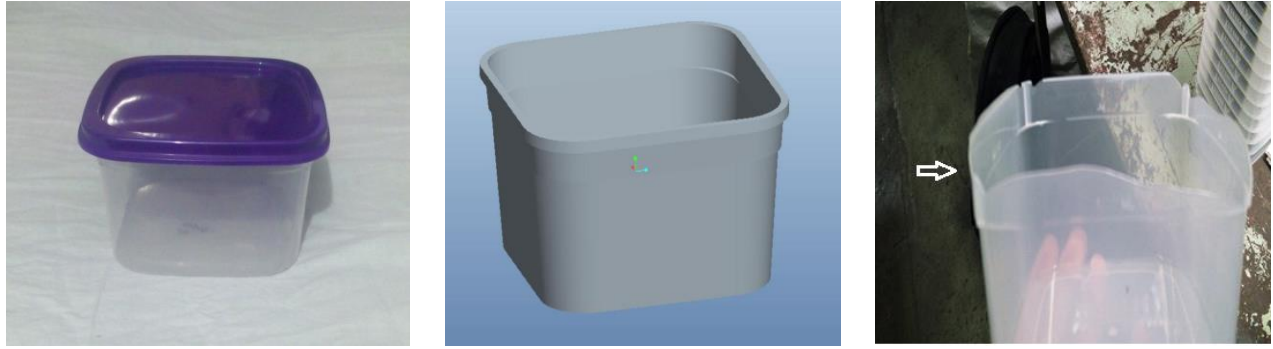


Figure 1 a) Actual part, b) 3D model of container in creo2.0, c) Container with short shot defect.

3.1. Material specifications

- Material - Polypropylene
- Material Type – Thermoplastic
- Generic Name – PP
- Supplier - Indian Oil
- Trade Name - PROPEL1250MG
- MFI – 12
- Fiber Percent - 0.00%
- Melt temperature range - 150-260°C
- Mold temperature range - 30-70°C
- Ejection temperature - 117°C
- Freeze temperature - 127°C

4. METHODOLOGY

To achieve optimum conditions of process parameters, several iterations were conducted on Moldex3D simulation software as shown in table 1. Initially the current process parameter which gives rise to short shot defect were analysed to study the filling pattern of container and short shot percentage. The output report generated in first iteration were studied and influencing parameters which are filling time, melt temperature, injection and packing pressure adjusted accordingly. While adjusting the parameters care should be taken not to exceed cycle time beyond specified value. If the defect is still coming in the second iteration then value of process parameters should be increased again. Similar process is achieved to get optimum result.

Table 1 Trials to achieve optimum conditions

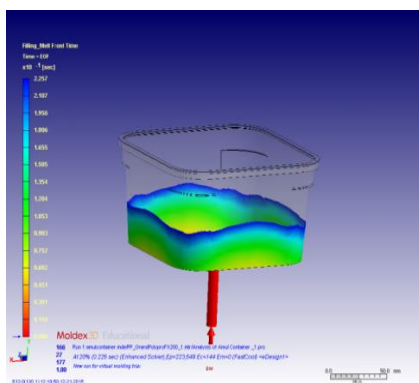
| Process Parameter | Run 1 | Run 2 | Run 3 | Run 4 | Run 5 |
|--------------------------|---------|---------|---------|---------|---------|
| Filling Time(sec.) | 0.30 | 0.45 | 0.53 | 0.68 | 0.79 |
| Melt Temperature(°C) | 130 | 147 | 170 | 200 | 220 |
| Mold Temperature(°C) | 50 | 50 | 50 | 50 | 50 |
| Injection Pressure(MPa) | 110 | 117 | 129 | 135 | 140 |
| Packing Time(sec.) | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 |
| Packing Pressure(Mpa) | 90 | 110 | 127 | 150 | 160 |
| Mold Open Time(sec.) | 3.01 | 3.01 | 3.01 | 3.01 | 3.01 |
| Ejection Temperature(°C) | 117 | 117 | 117 | 117 | 117 |
| Air Temperature(°C) | 25 | 25 | 25 | 25 | 25 |
| Cooling Time(sec.) | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| Cycle Time(sec.) | 12.90 | 13.06 | 13.14 | 13.29 | 13.40 |
| Analysis Type | Filling | Filling | Filling | Filling | Filling |

5. RESULT AND DISCUSSION

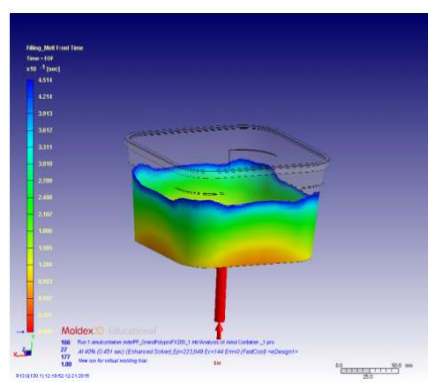
Filling pattern of molten metal in container is as shown in fig.2 and fig.3. Filling pattern results determine that all flow paths fill at the same time which results in balanced flow. The diagrams show the contour colors that represent the flow of plastic into the part and has its unique significance. The result is dark blue at the start of the injection, and the last areas to fill are red. As the percentages of yellow and red increase, the difficulty in molding the part will increase and the part quality will decrease. If the part is a short shot, the section that did not fill has no color. As expected, the container filled very unequally and shows the formation of unfilled sections and burrs. The incomplete filling is one type of the defect that normally will appear either a lack of fluidity in the molten polymer or incorrect filling time. It can reduce part quality due to variation in surface appearance, poor packing, high stresses, and non- uniform orientation of the polymer molecules.

4.1. Operating Conditions before Analysis

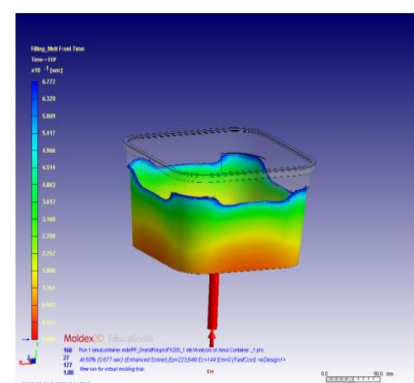
- Filling Time – 0.30sec.
- Melt Temperature – 130°C
- Mold Temperature – 50°C
- Injection Pressure – 110MPa
- Packing Pressure – 90MPa



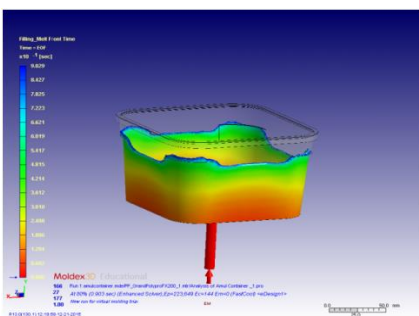
20% filling



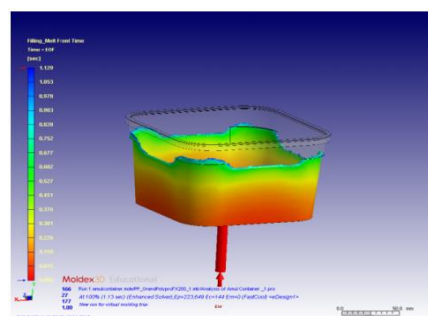
40% filling



60% filling



80% filling



100% filling

| No | Time(sec) | Pres(MPa) | Q(cc/sec) | Fill(%) | CPU(sec) |
|------------------------------|-----------|-----------|-----------|---------|----------|
| 101 | 0.319 | 77.00 | 42.20 | 56.851 | 3269 |
| 102 | 0.361 | 77.00 | 33.43 | 59.730 | 3323 |
| 103 | 0.420 | 77.00 | 25.22 | 62.977 | 3378 |
| writing data, please wait... | | | | | |
| 104 | 0.495 | 77.00 | 17.44 | 66.063 | 3455 |
| 105 | 0.592 | 77.00 | 10.63 | 68.836 | 3517 |
| 106 | 0.732 | 77.00 | 5.45 | 71.273 | 3579 |
| writing data, please wait... | | | | | |
| 107 | 0.931 | 77.00 | 2.10 | 73.058 | 3664 |
| 108 | 1.316 | 77.00 | 0.52 | 74.381 | 3738 |

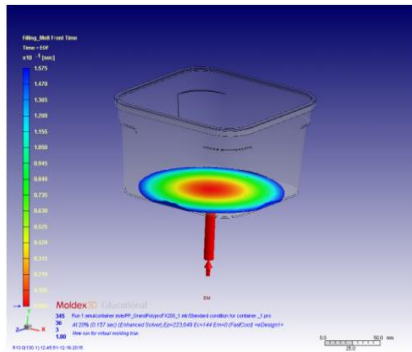
Filling log file

Figure 2 Filling pattern of container before analysis

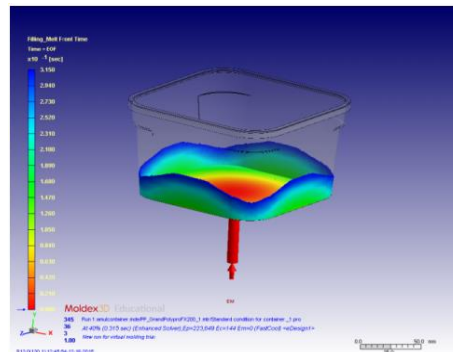
As the result shows, filling calculation stops before 100% in filling log file, molten metal fills up to 74.38% as shown in fig. 2. Molten metal is highly unbalanced and incomplete.

4.2. Operating Conditions after Analysis

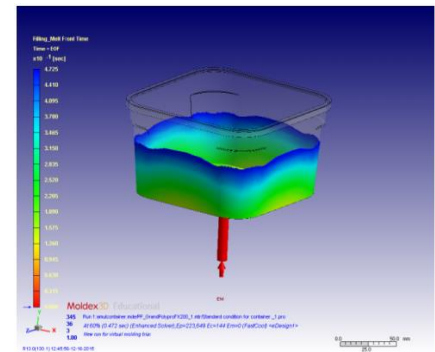
- Filling Time – 0.79sec.
- Melt Temperature – 220°C
- Mold Temperature – 50°C
- Injection Pressure – 140Mpa
- Packing Pressure – 160Mpa



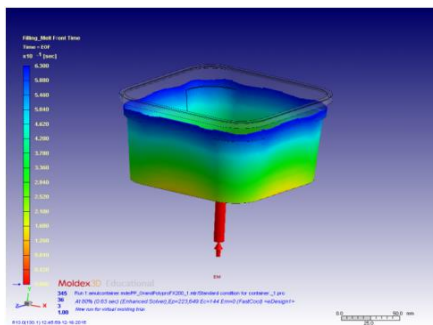
20% filling



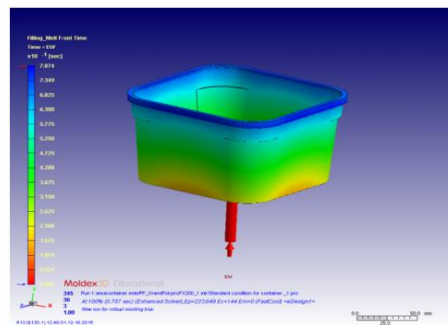
40% filling



60% filling



80% filling



100% filling

| No | Time(sec) | Pres(MPa) | Q(cc/sec) | F111(%) | CPU(sec) |
|-----|-----------|-----------|-----------|---------|----------|
| 101 | 0.555 | 33.36 | 77.22 | 69.985 | 3172 |
| 102 | 0.582 | 34.12 | 77.22 | 73.468 | 3204 |
| 103 | 0.601 | 35.04 | 77.22 | 75.827 | 3236 |

| No | Time(sec) | Pres(MPa) | Q(cc/sec) | F111(%) | CPU(sec) |
|-----|-----------|-----------|-----------|---------|----------|
| 104 | 0.623 | 35.97 | 77.22 | 78.644 | 3288 |
| 105 | 0.648 | 36.64 | 77.22 | 81.794 | 3320 |
| 106 | 0.667 | 37.50 | 77.22 | 84.143 | 3353 |
| 107 | 0.694 | 38.45 | 77.22 | 87.574 | 3384 |
| 108 | 0.717 | 39.55 | 77.22 | 90.597 | 3417 |
| 109 | 0.748 | 40.46 | 77.22 | 94.436 | 3450 |
| 110 | 0.769 | 40.79 | 77.22 | 97.118 | 3482 |

>>> Switching over from filling to packing phase

writing data, please wait...

| No | Time(sec) | Pres(MPa) | Q(cc/sec) | F111(%) | CPU(sec) |
|-----|-----------|-----------|-----------|---------|----------|
| 111 | 0.787 | 41.90 | 77.22 | 99.452 | 3529 |
| 112 | 0.787 | 41.90 | 77.22 | 100.000 | 3529 |

Filling log file

Figure 3 Filling pattern of container after analysis

When simulation is carried out with improved process parameters, the result shows 100% filling of material at the last time step in filling log file. The simulation shows balanced and complete filling of molten metal under uniform pressure.

6. CONCLUSION

Moldex3D CAE software provides the true 3D simulation and visualization of part on user interface to study flow pattern during filling analysis. Result shows that, current process condition shows incomplete filling (74.38) of container due to incorrect selection of process parameters. From simulation report we came to know that filling time, melt temperature, injection pressure and packing pressure are prominent parameters to decide short shot criterion. While other are assisting parameters in filling analysis. Therefore we optimized the process parameters to overcome short shot defect. Simulation report shows that we can achieve 100% filling of molten metal and avoid defect in future. Implementation of Moldex3D simulation software is essential where cycle time of part is too long in terms of hours and raw material is so costly that any wastage of material during trial industry, can't afford.

REFERENCE

1. Hyeyoung Shin and Eun-Soo Park (2013), "Analysis of Incomplete Filling Defect for Injection-Molded Air Cleaner Cover Using Moldflow Simulation", *Hindawi Publishing Corporation*, Volume 2013, Revised 21 May 2013, Republic of Korea.
2. Prof. M.G. Rath and Mr. Manoj D. Salunke (2012), "Reduction of Short Shots by Optimizing Injection Molding

- Process Parameters", *IAEME*, Volume 3, Issue 3, pp.285-293, India.
3. Satoshi Kitayama, Ryosuke Onuki, Koetsu Yamazaki (2014), "Warpagereduction with variable pressure profile in plastic injection molding via sequential approximate optimization", 27 February 2014, Springer-Verlag London.
 4. HasanOktem, Tuncay Erzurumlu, Ibrahim Uzman (2006), "Application of Taguchi optimization technique in determining plastic injection molding process parameters for a thin-shell part", *Materials and Design*, 3 March 2006, Turkey.
 5. Y. K. Shen, P. H. Yeh, and J. S. Wu (2001), "Numerical simulation for thin wall injection molding of fiber reinforced thermoplastics, "*International Communications in Heat and Mass Transfer*, vol.28, no. 8, pp. 1034–1042.
 6. S. Dairanieh, A. Haufe, H. J. Wolf, and G. Mennig (1996), "Computer simulation of weld lines in injection molded poly (methyl methacrylate)," *Polymer Engineering and Science*, vol. 36, no. 15, pp. 2050–2057.
 7. Bikas A, Pantelelis N, Kanarachos A (2001) Computational tools for the optimal design of the injection moulding process. *J Mater Process Technol* 122:112–126.
 8. H. Shin and E.-S. Park (2009), "Analysis of crack phenomenon for injection-molded screw using moldflow simulation," *Journal of Applied Polymer Science*, vol. 113, no. 4, pp. 2702–2708.
 9. Lee Tin Sin, W.A.W.A. Rahman, A.R. Rahmat, Tiam-Ting Tee, SooTueen Bee, Low Chong-Yu (2011), "Computer aided injection moulding process analysis of polyvinyl alcohol–starch green biodegradable polymer compound", *Journal of Manufacturing Processes*, 5 August 2011